Discrepancies with RDRA WP

Draft Final RDRA WP PG 48

and TerraTherm and discussed with the AF, EPA, and ADEQ prior to termination of steam injection.

When the determination is made to transition to EBR, steam injection will be discontinued and the steam front will be allowed to collapse. At this point the SEE system will only continue with liquid and vapor extraction to provide additional mass recovery and continued contaminant containment during the initial cool down of the TTZ.

Once steam injection ceases, extraction wells in the PMGAA cell phone lot will be connected by subsurface piping to the extraction system so that use of the original cell phone lot entrance can be restored. Extraction will continue for about 90 days after which the remedy will be in the EBR phase.

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Develop an EBR field test plan?? Underground piping for extraction??

4.3 Enhanced Bioremediation Implementation

EBR treatment of the LNAPL-impacted zones outside the SEE TTZs, and to the extent necessary, residual contamination within the TTZs will be accomplished in seven steps as follows:

1. Develop and implement an EBR Field Test Plan;
2. Select the TEA for EBR;
3. Analyze SEE treatment operations data (e.g., TEA and contaminant concentrations in groundwater wells and extracted groundwater, temperatures, water chemistry and biological parameters);
4. Refine the EBR system design and document in an RD/RAWP update including well field and process equipment selection and groundwater sampling to evaluate post SEE conditions;

5. Install EBR system including wells, underground pipes, and process equipment;
6. Operate, maintain, monitor EBR system
7. Shut down and decommission EBR system

The conceptual approach for EBR is presented in Section 3.5 and Appendix E. The development of the EBR Field Test Plan for the selection of TEA and refinement of EBR design will begin following the finalization of the RD/RAWP with implementation of the EBR Field Test planned for just prior to SEE startup. Since the finalization of the EBR RD will occur following the startup of SEE, the schedule allows for a pragmatic approach for development of the final EBR design. At the conclusion of the EBR Field Test, SEE operations will be underway and the EBR RDRA WP update will be completed. Site-specific properties including biotic (e.g., enhanced maximum utilization rates) and abiotic (e.g., dispersivity) parameters will be used to refine the EBR design and implementation.

Because the EBR recirculation system will require a longer operation time than SEE and the system footprint will extend into areas actively used by adjacent property owners, pipelines will be installed underground. Wellhead vaults will be installed at each remediation well to allow for access to wells, pumps, instrumentation, and transmission line junctions. Pipelines from each well will be brought to a central remediation compound located within ST012. Bedding sand and compacted trench spoils will be used to backfill transmission line trenches and the site surface will be restored (e.g., grading or asphalt patching).

Flow regulating manifolds for each grouping of wells (e.g., UWBZ injection wells) will be located in a control house at the remediation compound. Operational surge and mixing tanks (if required) and oil/water separators will be placed between extraction and injection manifolds to facilitate control of delivery pressures and conditioning of recirculated liquids. In-well pressure

Appendix E EBR workplan Pg 4-9

This presumes there will be considerably less LNAPL following SEE than what is actually estimated

Table E-4.8 Estimated LNAPL Volume in EBR Treatment Zones Following SEE Treatment

Zone	LNAPL Volume (gallons)[1]	LNAPL Saturation[2] (%)
CZ	6,290	1.53%
UWBZ	340,525	6.27%
LPZ	30,416	0.59% – 1.19%
LSZ	105,861	2.65%

Notes:
[1]Based on RD/RAWP Appendix B for conservative LNAPL interpretation for LNAPL outside of the TTZs in the EBR treatment zones assuming no removal outside the TTZs during SEE.
[2]Calculated LNAPL saturation from Pre-Design Investigation results (see RD/RAWP Appendix B)
% – percent
CZ – Cobble Zone
LNAPL – light non-aqueous phase liquid
LPZ – Low Permeability Zone
LSZ – Lower Saturated Zone
SEE – steam enhanced extraction
UWBZ – Upper Water Bearing Zone

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Table E-4.9 Initial LNAPL Saturation and Corresponding Component Concentration in LNAPL

Layer	LNAPL Saturation Post SEE	Concentration of Benzene in LNAPL post SEE (lbs/ft^3)[1]	Concentration of Other LNAPL Constituents (lbs/ft^3)
CZ - TTZ	0.153%	0.0053	49.11
CZ - EBR	1.53%	0.0527	49.07
UWBZ - TTZ	0.627%	0.00216	49.11
UWBZ - EBR	6.27%	0.216	48.96
LPZ – BETWEEN SEE	0.59%	0.0206	49.08
LPZ – OUTSIDE SEE	1.19%	0.0412	49.07
LSZ – TTZ	0.265%	0.00913	49.10
LSZ – EBR	2.65%	0.0913	49.04

Notes:

[1]Benzene faction is assumed at 10 percent of the value observed fraction in samples from the TEE pilot test report (BEM, 2010)

What happened to 60' well spacing / 5 point injection pattern?

4.1 EBR Well Field Design

Remediation well spacing and positioning; screen placement; and injection/extraction rates for the conceptual EBR system were designed using the groundwater flow model. A typical five-point pattern, a square treatment cell consisting of a centrally located injection well surrounded by four extraction wells, on 60-foot spacing was used for the conceptual layout of the UWBZ and LSZ well fields. Although these units have different hydrogeologic properties, the 60-foot spacing was determined to yield a sufficient mixing time and dispersion between injection and extraction in each zone and allow for the collocation of wells within single boreholes thereby minimizing the cost and impact of drilling.

This 60-foot well spacing was determined to be optimal by an iterative process using the groundwater flow model to assess various configurations of the well fields within the geometry of the treatment areas. Beyond an approximate well spacing of 75 feet results from the model revealed that sufficient extraction pumping could not be achieved because of limitations associated with the permeability and storage of the aquifer and subsequent loss of injectate to the natural gradients in these gaps between extraction well capture zones. At well spacings between 65 feet and 75 feet the average travel time between injection and extraction well ranged between approximately 400 and 500 days in the UWBZ and LSZ. Dropping the well spacing to 60 feet across the two zones nearly halved the travel time between wells revealing that at 60-foot spacing in the UWBZ and LSZ, there is communication between injection fronts and extraction well cone of depression flow fields. Furthermore, assuming a transverse dispersivity of 20 feet a 60-foot well spacing is advantageous for a five spot pattern considering the anticipated mixing during and following active injection and extraction. As discussed in the main body text of the RD/RAWP, dispersivity for each hydrogeologic unit will be refined using inject-withdraw tests and these results as well as results from the SEE treatment will be used to refine the EBR design including well spacing and placement.

If sulfate is selected as the TEA, the design basis will be to deliver and distribute sulfate to the EBR treatment areas such that a sufficient amount of sulfate is present following 18 months of active recirculation to support continued reduction of contaminants in all phases such that dissolved COCs are at or below cleanup levels within about 15 years following the end of active recirculation. Similar to oxygen, the sulfate recirculation period may be further evaluated in the final design and could extend up to 3 years. This design basis assumes that elevated sulfate concentrations will be sustained for a prolonged period after recirculation ceases based on the relatively high solubility of sulfate and the slower utilization rate by sulfate-reducing bacteria compared to aerobic bacteria. Continued degradation during MNA will remain anaerobic, sustained by the inflow of electron acceptors with groundwater from upgradient of ST012. Other design criteria common to either TEA approach are as follows:

1. Mix and homogenize the contaminant within the treatment zone to facilitate greater contact between aquifer-borne bacteria;
2. Distribute TEA throughout the treatment zone; and
3. Assess and amend, if necessary, for essential nutrients and minerals.

Are these the EBR performance criteria? Are they realistic given current remaining concentrations?:

E-4.15. Table E-4.15 also shows the predicted average and maximum dissolved benzene concentrations eight years following the cessation of active EBR recirculation.

Table E-4.15 Predicted Maximum and Average Dissolved Benzene Concentrations Following Sulfate-Reducing EBR

Hydrostratigraphic Zone	Date (month/year)	Predicted Benzene Concentration (µg/L)		Notes
		Average	Maximum	
Cobble Zone	04/2017	21	27	End of EBR Recirculation/TEA Addition
	04/2025	1.25	7.8	~8 years following EBR
	01/2031	0.08	0.95	~15 years following EBR
Upper Water Bearing Zone	04/2017	210	1,400	End of EBR Recirculation/TEA Addition
	04/2025	5.5	9.5	~8 years following EBR
	01/2031	1.0	3.3	~15 years following EBR
Lower Saturated Zone	04/2017	31	270	End of EBR Recirculation/TEA Addition
	04/2025	1.9	6.8	~8 years following EBR
	04/2031	0.64	2.8	~15 years following EBR

__Notes:__
~ - approximately
µg/L – micrograms per liter
EBR – enhanced bioremediation
TEA – terminal electron acceptor

Immediately following sulfate-reducing EBR recirculation (Table E-4.15) the model predicts that dissolved benzene concentrations are below approximately 27 µg/L in the CZ, 1,400 µg/L in the UWBZ, and 270 µg/L in the LSZ. Within eight years following sulfate-reducing EBR dissolved benzene concentrations drop and the maximum concentration of benzene predicted in the UWBZ is 9.5 µg/L. By 2031, the benzene concentrations in each of the hydrostratigrapic zones are predicted to be below 5 µg/L.

RTCS – Comittment to multiple lines of evidence approach to evaluating shutdown criteria was agreed to at the workplan rather than specific criteria; but did not even meet 10% removal criteria.

3				The criteria to be used to determine when to terminate steam injection and initiate EBR should be prescribed in the RD/RAWP. The criteria were discussed during the November 19, 2013 BCT meeting, and the points that were brought up during the discussion, which included the fact that multiple lines of evidence, not just criteria, will be considered when deciding when to terminate steam injection, need to be incorporated into the RD/RAWP. It should be made clear that first the temperature criteria must be met in the TTZ (excluding the low permeability zone (LPZ), which is not likely to take steam), and verified by the energy balance, and the pressure cycling completed (showing no	Multiple lines of evidence will be used to support the discussion to terminate steam injection. The criteria presented at the BCT are in the RD/RAWP (Section 4.2.4) and have been clarified further in a tabular format similar to the BCT meeting presentation. The first two paragraphs of Section 4.2.4 have been combined and modified as follows: "The overall strategy for the selected groundwater remedy is presented in Section 3.2.2. Multiple lines of evidence will be used to support the discussion to terminate steam injection and transition to EBR. The primary factors for making the determination to transition from SEE to EBR are achieving

Item	Page	Section	Line(s)	EPA Comment	Air Force (AF) Response to Comment (RTC)
				additional significant increases in effluent vapor phase concentrations when steam injection is reduced) before consideration is given to whether recovery has decreased sufficiently from the peak recovery rate to justify termination of steam injection. We discussed during the BCT meeting that the expectation is that the benzene target criteria of 100 to 500 µg/L is high (i.e., lower concentrations are expected to be achieved) in the interior portion of the TTZ, but that this target was chosen because the modeling predicted that benzene concentrations greater than 500 µg/L would not degrade within the timeframe for achieving remedial goals. It must also be recognized that even when the recovery rate falls below 10 percent of the peak recovery rate, significant contaminant mass may still be recovered, and consideration should be given to whether it is more effective to continue recovering that mass via SEE or to try to degrade it with EBR.	target subsurface temperatures and diminishing mass removal rates. Throughout steam injection, AMEC and TerraTherm will closely monitor the performance of the SEE system. Evaluations of thermal operation will be ongoing to determine when the transition to the next phase is warranted. The specific criteria that will be considered in the decision making process for transition are shown in Table 4-2. The criteria will be considered in total with the weight of evidence from these multiple lines being used for decisions." A new Table 4-2 with the SEE to EBR transition criteria has been provided to replace the bullets in Section 4.2.4. The table includes the previous information supplemented with additional clarification as discussed in the November BCT meeting. The temperature goal does apply throughout the TTZs as described (not including the LPZ) and will be verified by the energy balance. However, local low-permeability zones may limit achievement of temperature goals in some areas. If such areas are identified, shut-down of steam will only be considered after operational adjustments are made to attempt to achieve the temperature goal and pressure cycling is completed in the area. A criterion has been added that pressure cycling be performed prior to consideration of

Item	Page	Section	Line(s)	EPA Comment	Air Force (AF) Response to Comment (RTC)
					whether recovery has decreased sufficiently from the peak recovery rate to justify termination of steam injection. A clarifying statement has been added indicating that lower benzene concentrations are expected in the interior compared to the perimeter and to describe the connection between the 500 µg/L criteria and the natural attenuation modeling. Text has been added to clarify that operational mass removal rates may continue below the 10 percent goal depending on the significance of continued mass removal, the status of COC concentrations (e.g., benzene) in extracted fluids, and the need/ability for EBR to achieve further degradation based on data collected during the EBR field test.

Concern about remaining mass estimate

Item	Page	Section	Line(s)	EPA Comment	Air Force (AF) Response to Comment (RTC)
2				EPA acknowledges that the SEE thermal treatment zone (TTZ) has already been expanded based on contamination found in borings installed during the pre-design investigation (as discussed in Section 3.2.2 of the RD/RAWP). However, a substantial amount of LNAPL will still remain unaddressed outside of the TTZ. According to Table 3-2 of the RD/RAWP, it is estimated that as much as 500,000 gallons of LNAPL remain outside the TTZ. EPA recognizes that there are constraints on expanding the SEE TTZ in some areas, such as Sossaman Road to the east and the Army Reserve Center to the west. However, we remain concerned that the extremely large amount of LNAPL estimated to be outside of the TTZ will be a significant hindrance to obtaining the RODA2 remedial goals within the desired timeframe of 20 years. Consideration should be given to fully defining the extent of LNAPL at the site, and possible ways to expand the SEE TTZ and/or the Enhanced Bioremediation (EBR) treatment zone.	It is the intent of the remedy to address all of the areas with LNAPL that contribute to groundwater contamination with either SEE or EBR. The SEE TTZs are designed to address the highest concentrations of contaminant mass while EBR is used to address lower residual LNAPL contamination outside of the TTZs. The extent of LNAPL will continue to be refined as part of the implementation as additional data is collected during drilling for SEE well installation and groundwater sampling, the EBR field test, and the final EBR design. The current EBR design extent is conceptual but is based on the more conservative potential LNAPL interpretation (i.e., higher LNAPL volume outside the SEE TTZ). While Table 3-2 indicates an estimated LNAPL volume of as much as 530,000 gallons outside the TTZ, this is the highest estimate based on a conservative distribution and literature saturation values. The LNAPL volume outside the TTZs is more likely a lower volume as represented by the range of values provided in Table 3-2 (140,000-530,000 gallons).